Measuring altered movement patterns of musicians - Accuracy of a Motion Capturing System outside laboratory conditions

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Background

- Use of **camera-based movement analysis** systems in medicine, kinesiology, biomechanics and in music health sciences

→ Identification of **altered/disturbed movement** patterns which lead to an **increased risk** of injury/illness for musicians (Davis,1997; Dixon,2011)

- Research project: "**Musikphysioanalysis**"

→ **Do musicians with playing-related musculoskeletal complaints show altered movement patterns?**

Background

- **high accuracy** of measurements under lab conditions (Everaert,1998; Windolf,2008)
- **Advantage:** Motion capturing systems are **not restricted** to lab use
- Measurement **under mobile conditions** in familiar/natural surroundings e.g. when rehearsing....

→**However, no data available of measurement accuracy out of lab**

Aim of study

To investigate whether **mobile use** of a marker based motion capturing system **impairs** measurement **accuracy** by means of a **two "pragmatic" experiments** (accuracy = absence of systematic and random error)

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Methods: Experiment 1

Wand swung in measurement volume (60 sec) in **three scenarios:**

- Out of lab (8m x 4m x 2.5m)
- Out of lab (5m x 3m x 2.5m)
- Lab (10m x 8m x 2.5m)

→ Compare measured distances to **true value (600.8 mm)**

Methods: Experiment 2

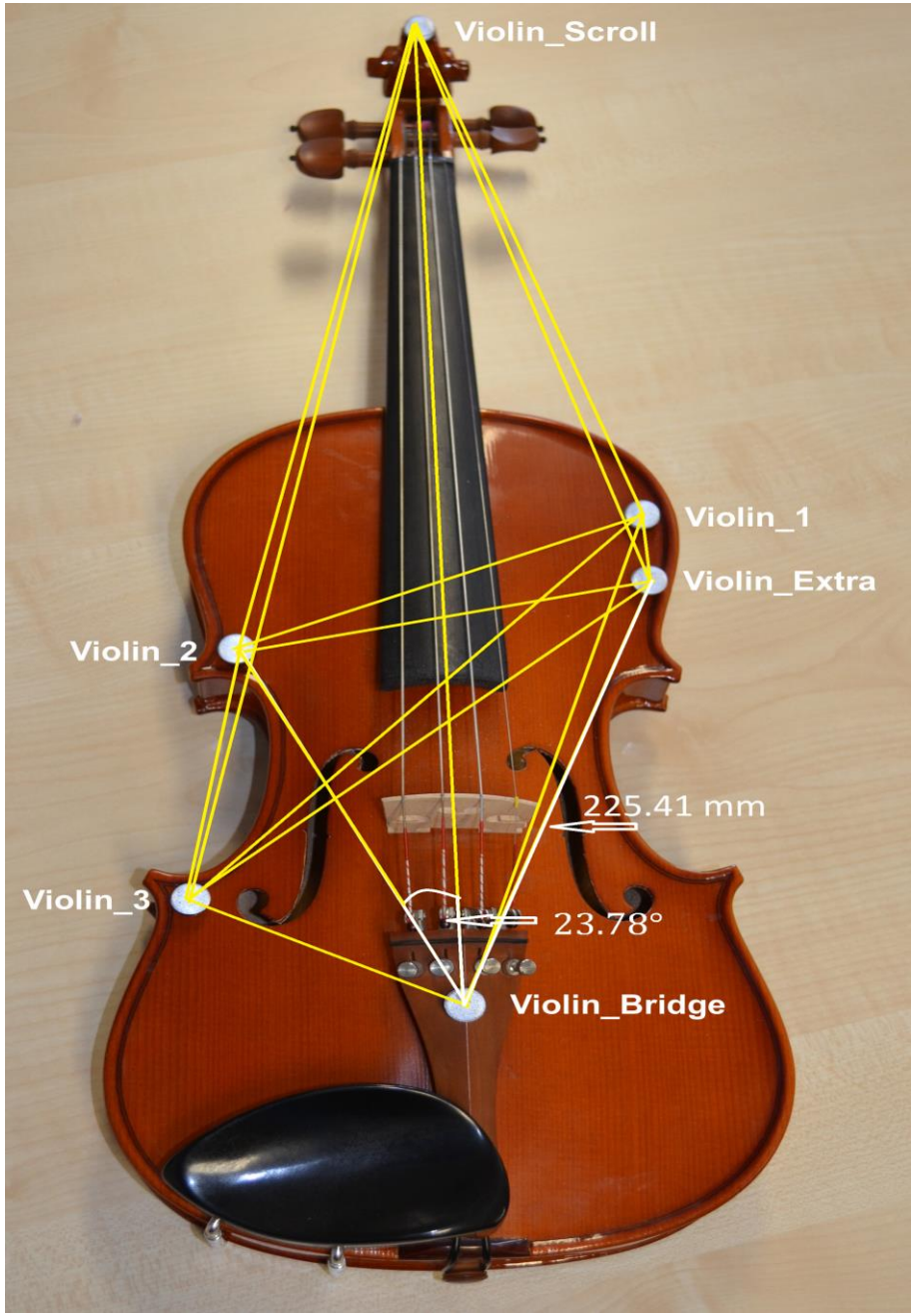
musician playing **chromatic scale** with „**markered**“ violin in in **three scenarios:**

- Out of lab (8m x 4m x 2.5m)
- Out of lab (5m x 3m x 2.5m)
- Lab (10m x 8m x 2.5m)

Comparison to „**true**“ values → under static conditions:

→distances (true values)

→ Angles (true values)



Methods: Calculating measurement error

- Calculation all **possibles distances/angles** between all markers
- Calculation of **deviation** from **true value** (measurement error) for each of the 9000 measurements for **each marker** seperately
- processed by **moving avarage**

Methods: Calculating measurement error

k denotes the number of markers m and n the number of measurements i

Deviation from true value of one single measurement $= x_{mi} - true\ value_{\mathrm{m}}$

Total error of marker$_{\mathrm{m}}$ TE$_{\mathrm{m}}$ $= \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_{mi} - true\ value_{\mathrm{m}})^2}$

→ Decomposition of **TE$_{\mathrm{m}}$** into **systematic** and **random** error for each marker

Random error of marker$_{\mathrm{m}}$ RE$_{\mathrm{m}}$ $= \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_{mi} - \bar{x}_{\mathrm{m}})^2}$

Systemtatic error of marker$_{\mathrm{m}}$ SE$_{\mathrm{m}}$ $= \bar{x}_{\mathrm{m}} - true\ value_{\mathrm{m}}$

Overall error across all markes → decomposition into: **squared avarage random error** of all markers and **variance of systematic errors** of all markers and **avarage systematic error of all markers**

$\sqrt{\overline{\mathrm{RE}}^2 + \frac{1}{k}\sum_{m=1}^{k}(\mathrm{SE}_m - \overline{\mathrm{SE}})^2 + \overline{\mathrm{SE}}^2}$ or $\sqrt{\frac{1}{kn}\sum_{m=1}^{k}\sum_{i=1}^{n}(x_{mi} - true\ value_{\mathrm{m}})^2}$

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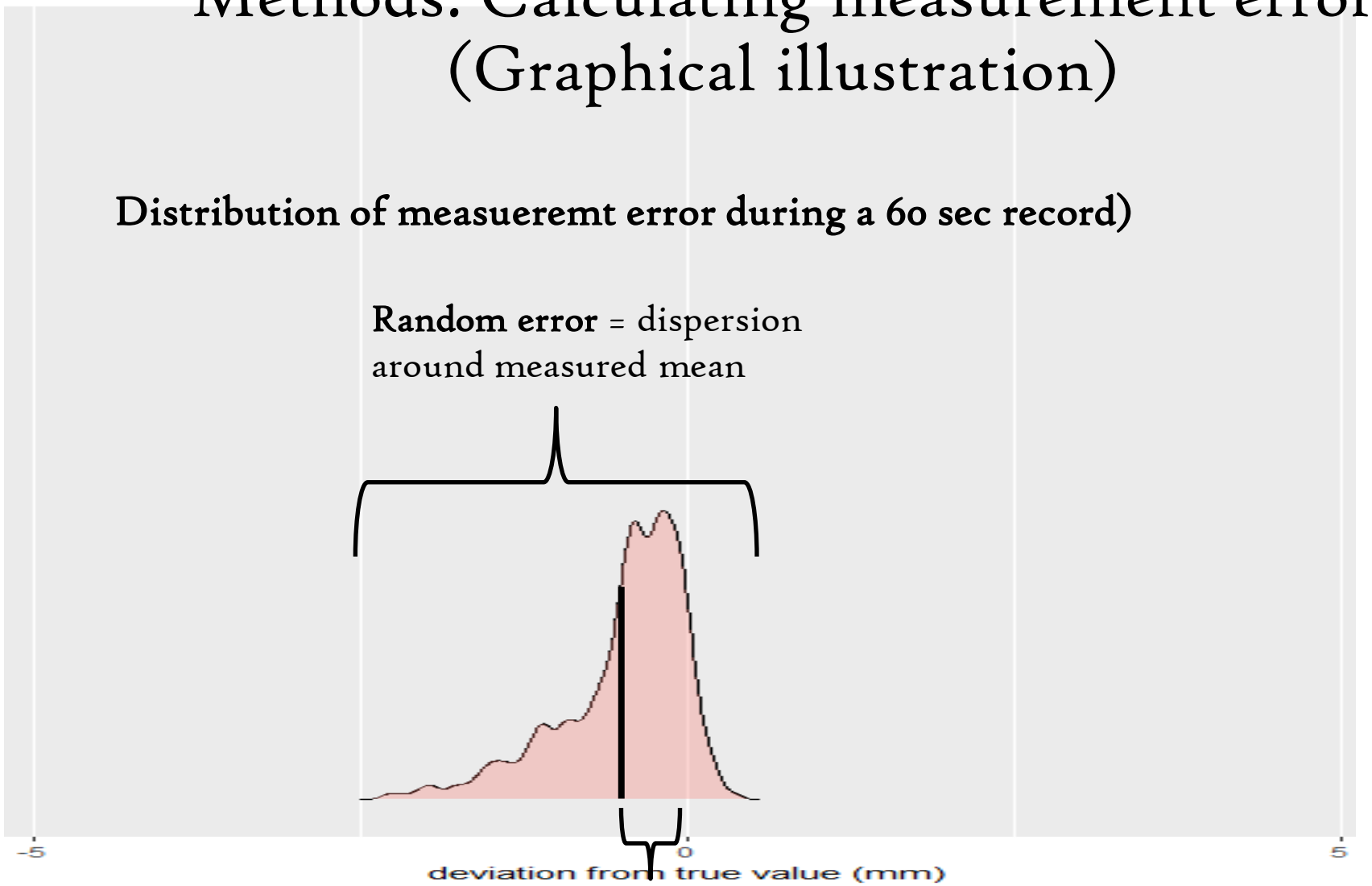
Methods: Calculating measurement error (Graphical illustration)

Distribution of measueremt error during a 60 sec record)

Random error = dispersion around measured mean

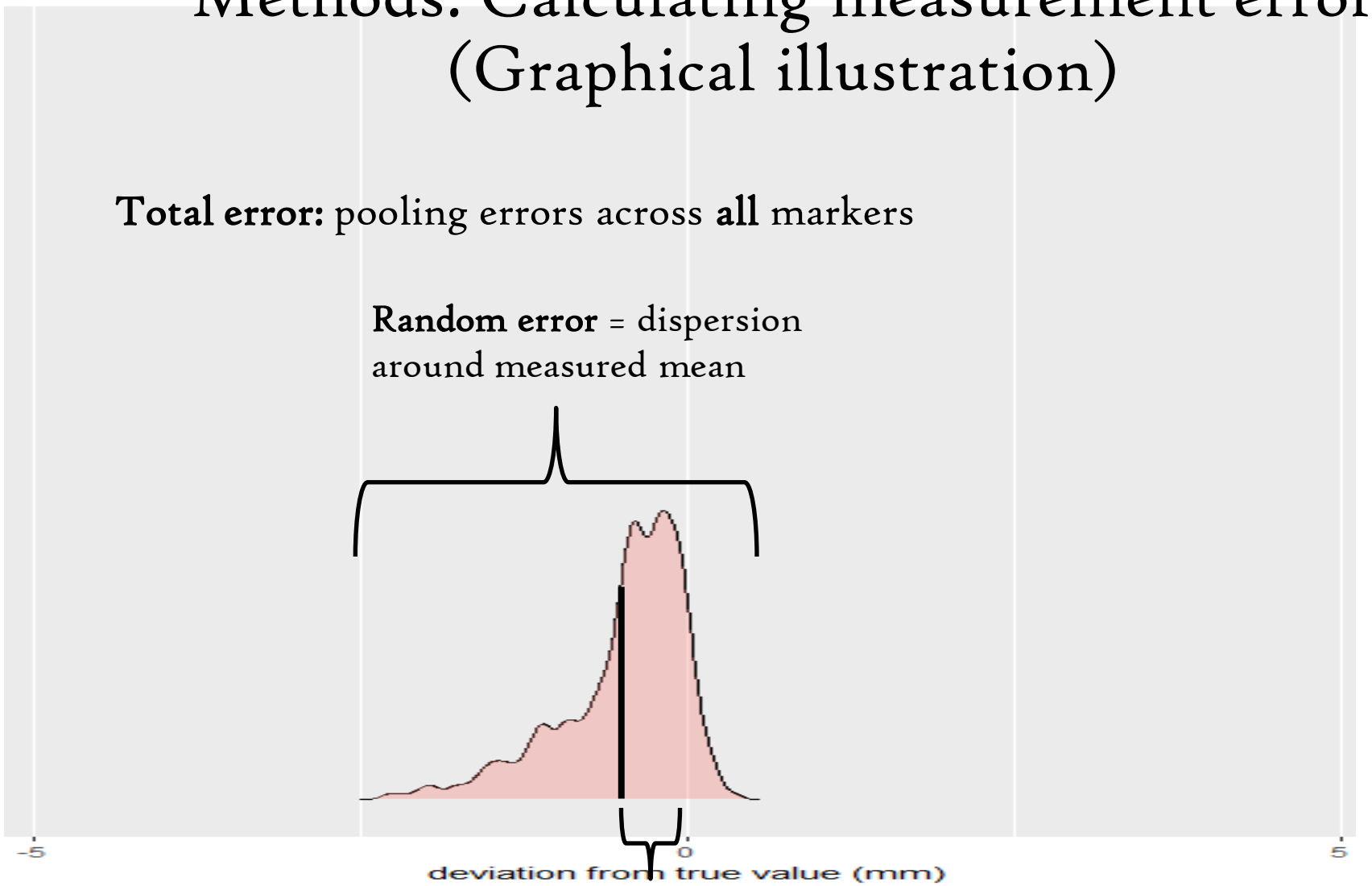


systematic error = mean deviation from zero (no deviation from true value)

Methods: Calculating measurement error (Graphical illustration)

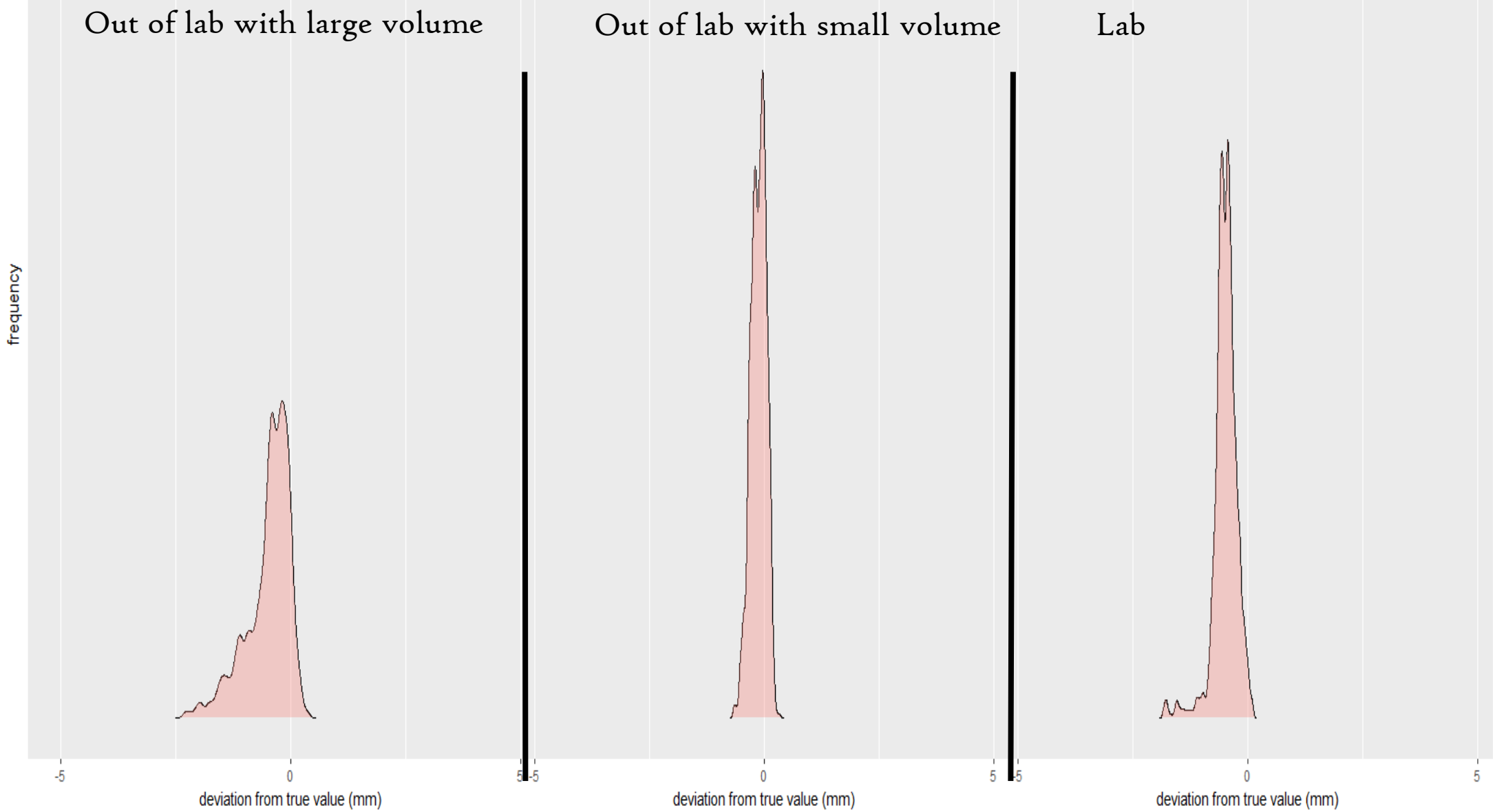
Total error: pooling errors across **all** markers

Random error = dispersion around measured mean

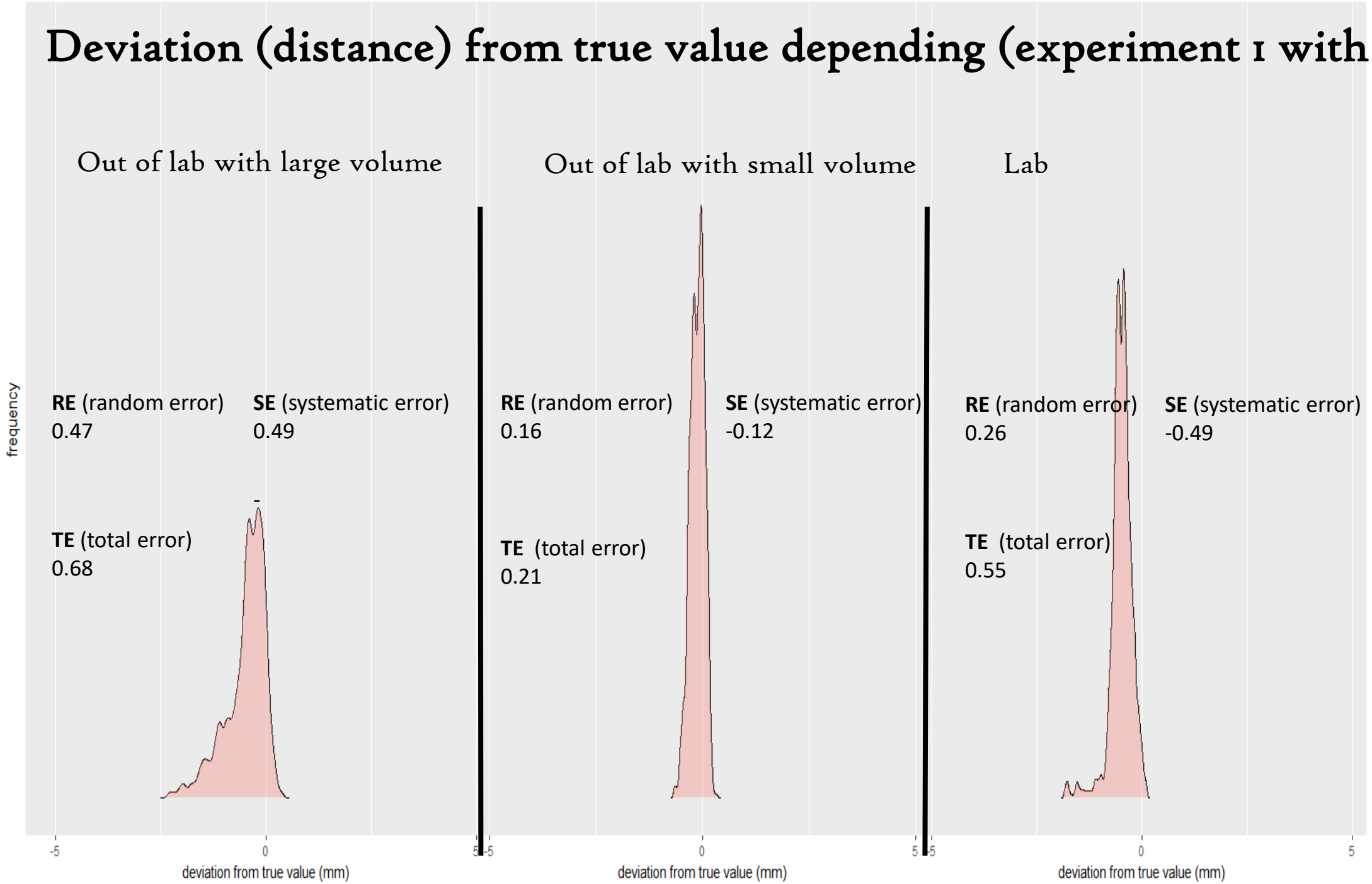


systematic error = mean deviation from zero (no deviation from true value)

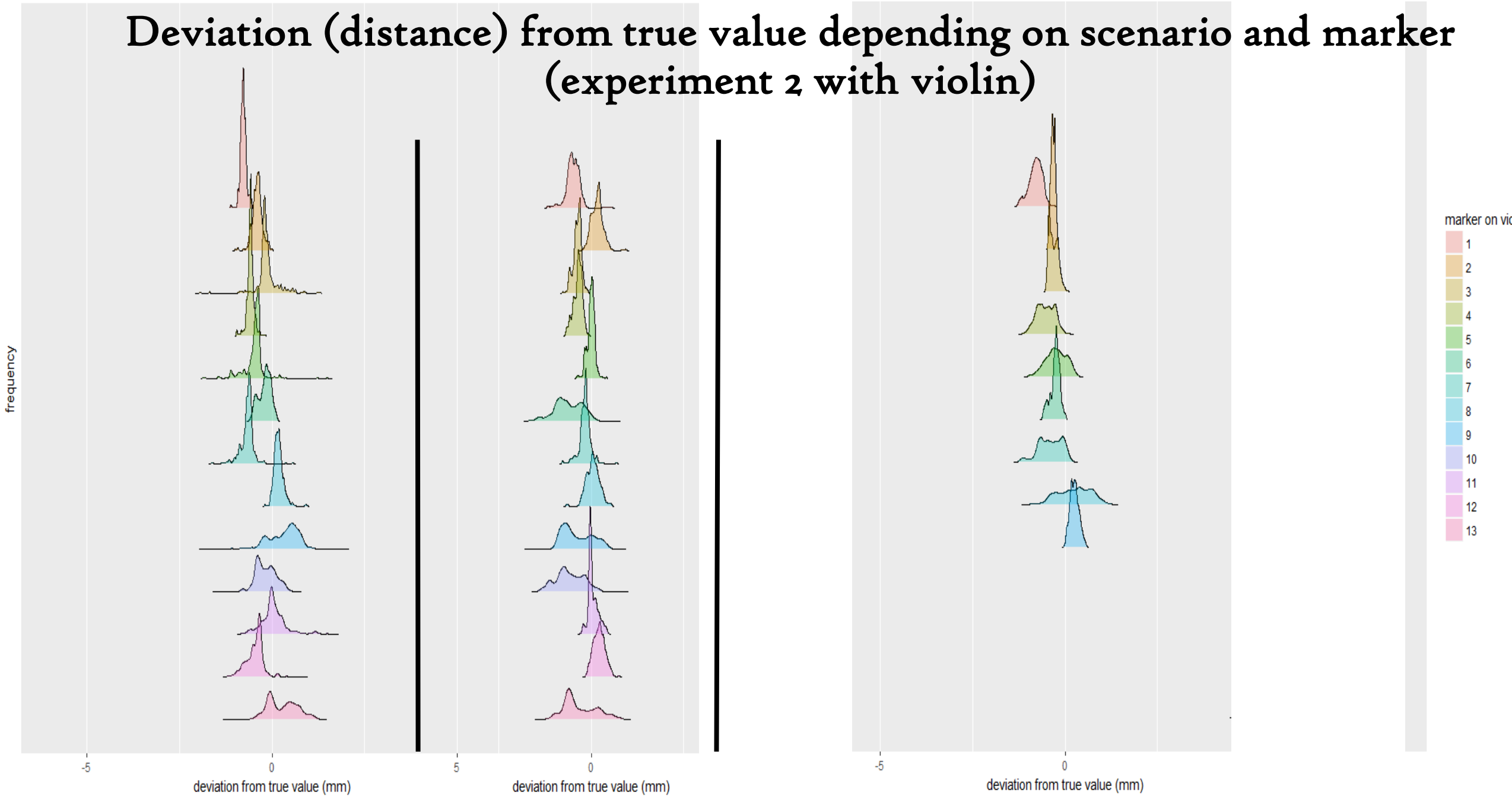
Deviation (distance) from true value depending (experiment 1 with wand)



Deviation (distance) from true value depending (experiment 1 with wand)



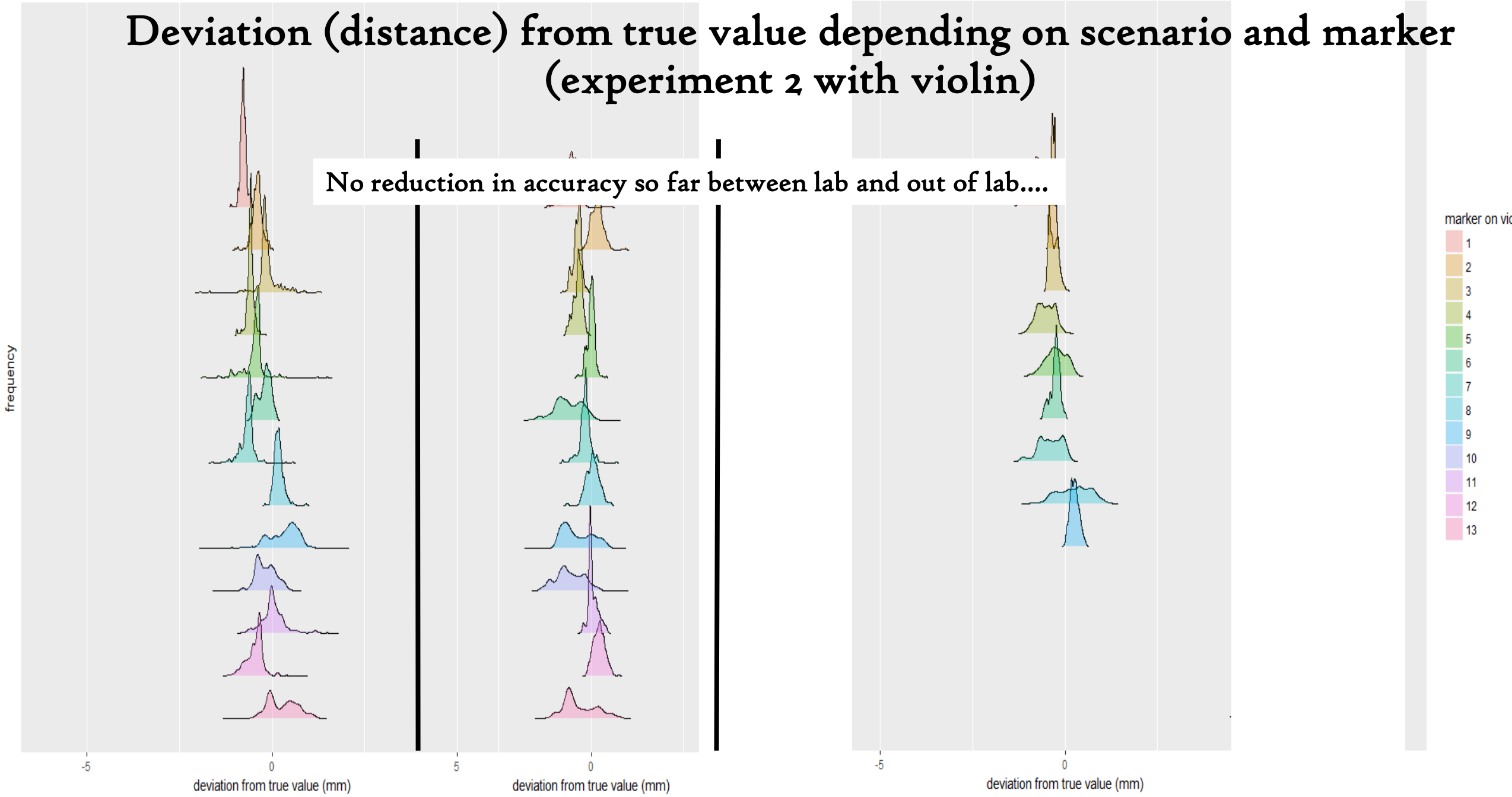
Deviation (distance) from true value depending on scenario and marker (experiment 2 with violin)



Out of lab with large volume Out of lab with small volume Lab

Deviation (distance) from true value depending on scenario and marker (experiment 2 with violin)

No reduction in accuracy so far between lab and out of lab....

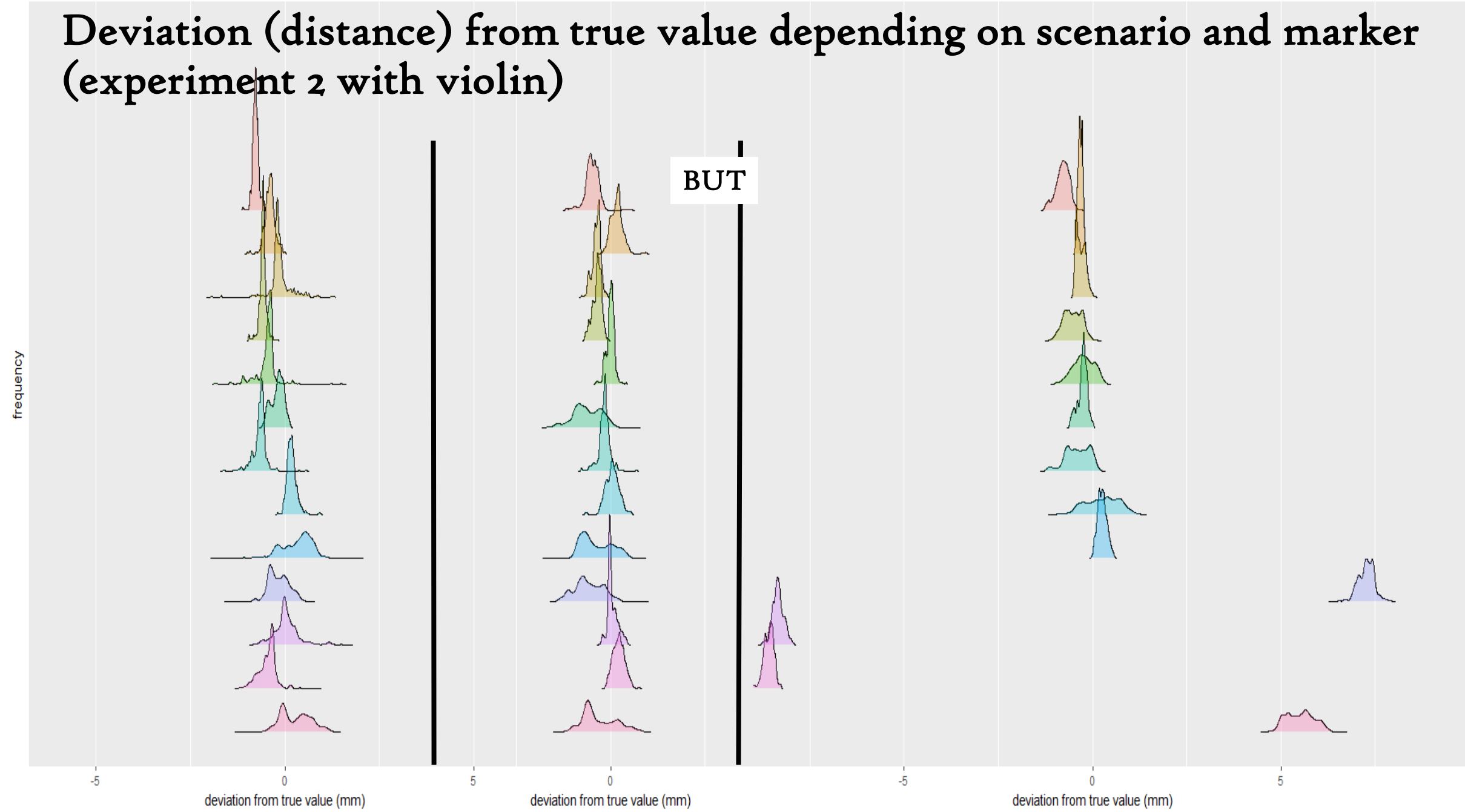


Out of lab with large volume

Out of lab with small volume

Lab

Deviation (distance) from true value depending on scenario and marker (experiment 2 with violin)



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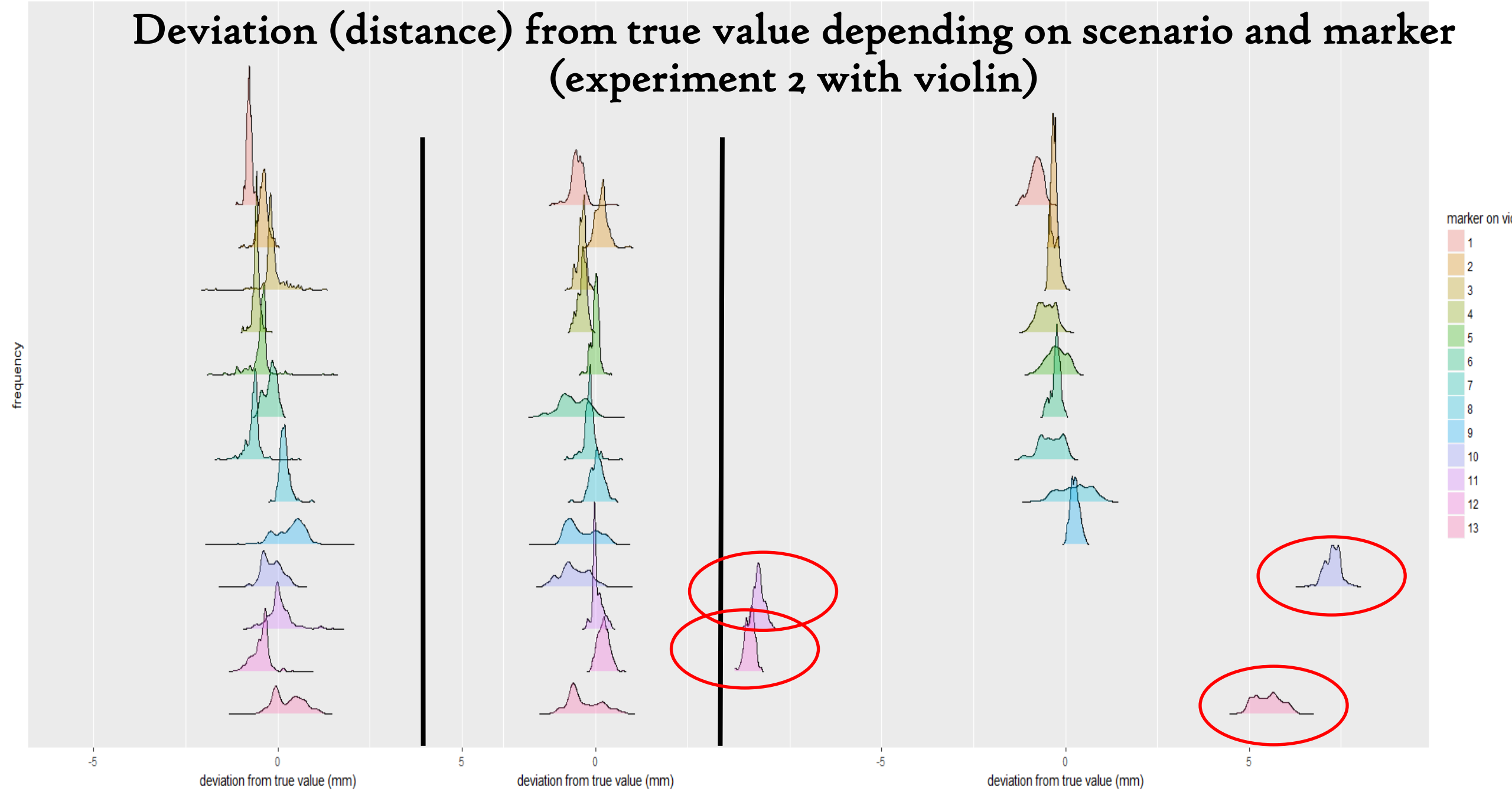
Deviation (distance) from true value depending on scenario and marker (experiment 2 with violin)



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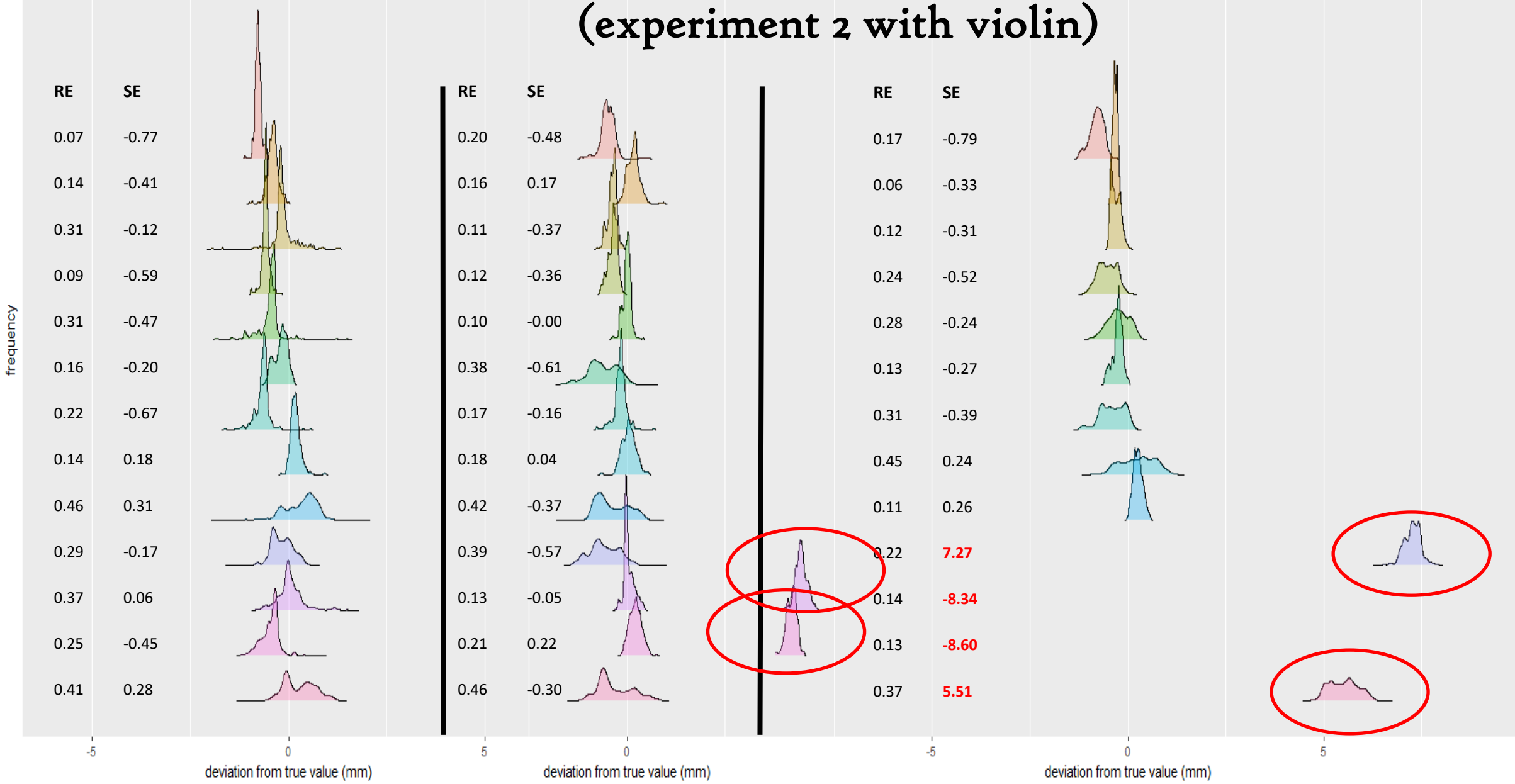
Deviation (distance) from true value depending on scenario and marker (experiment 2 with violin)



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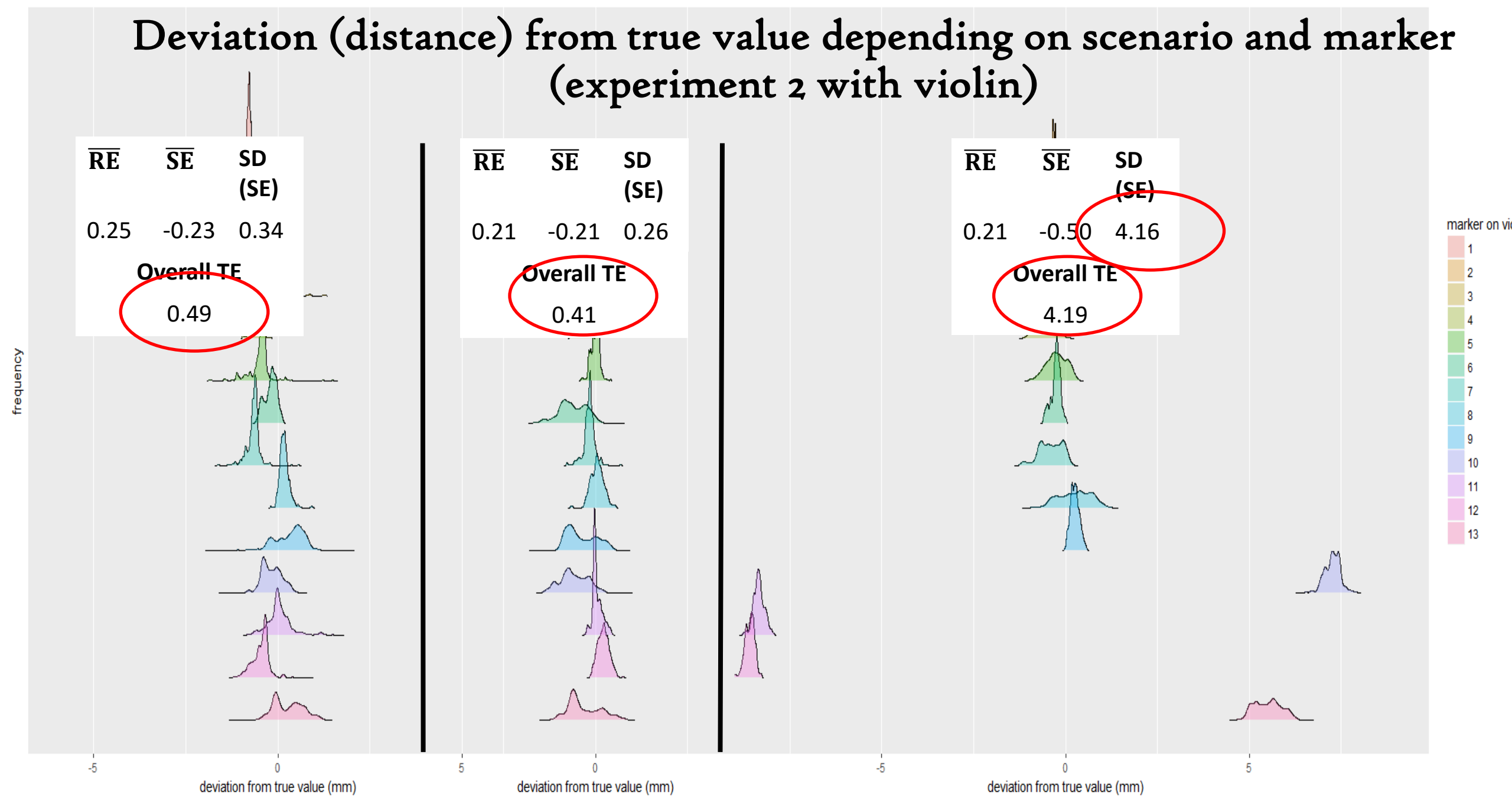
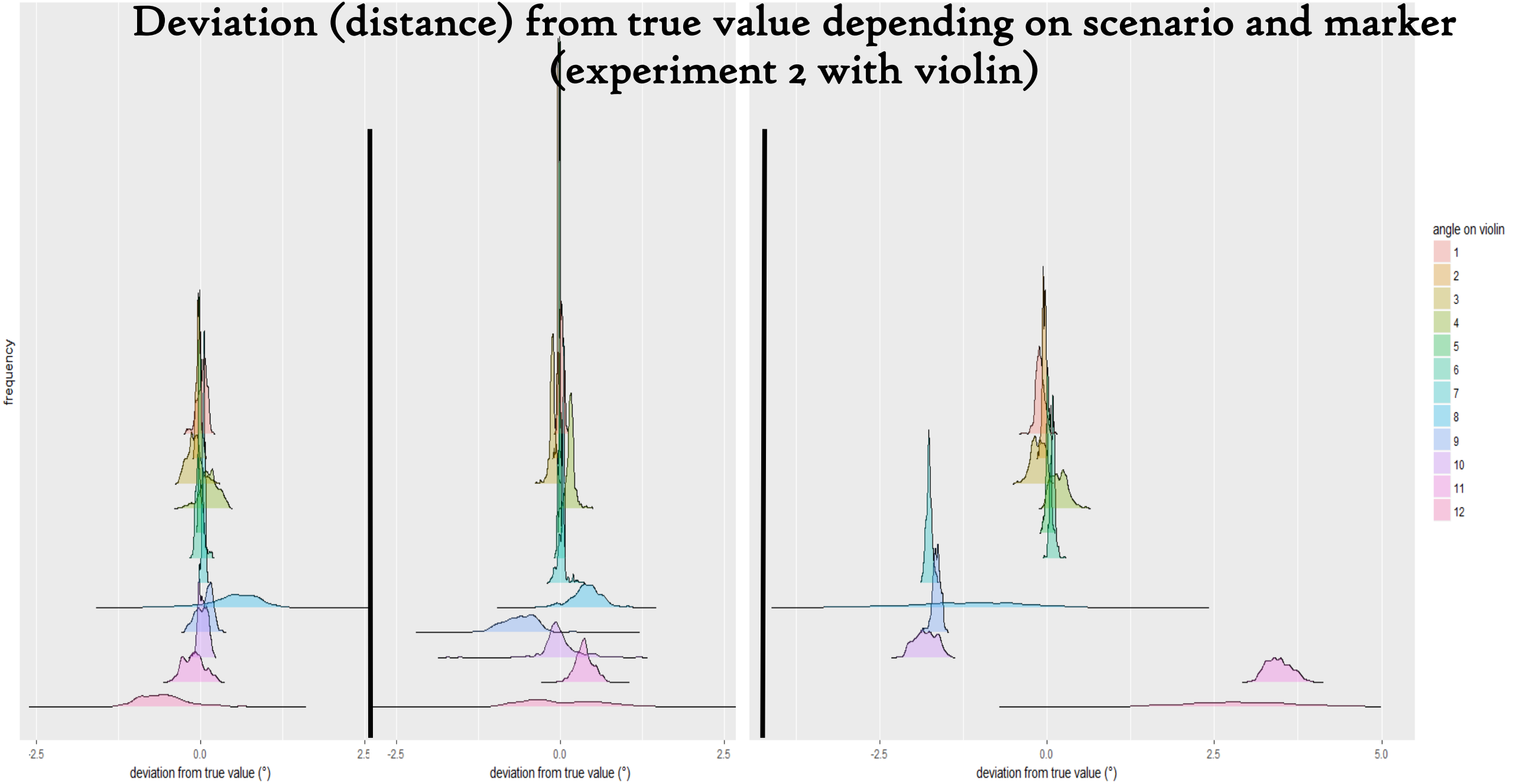


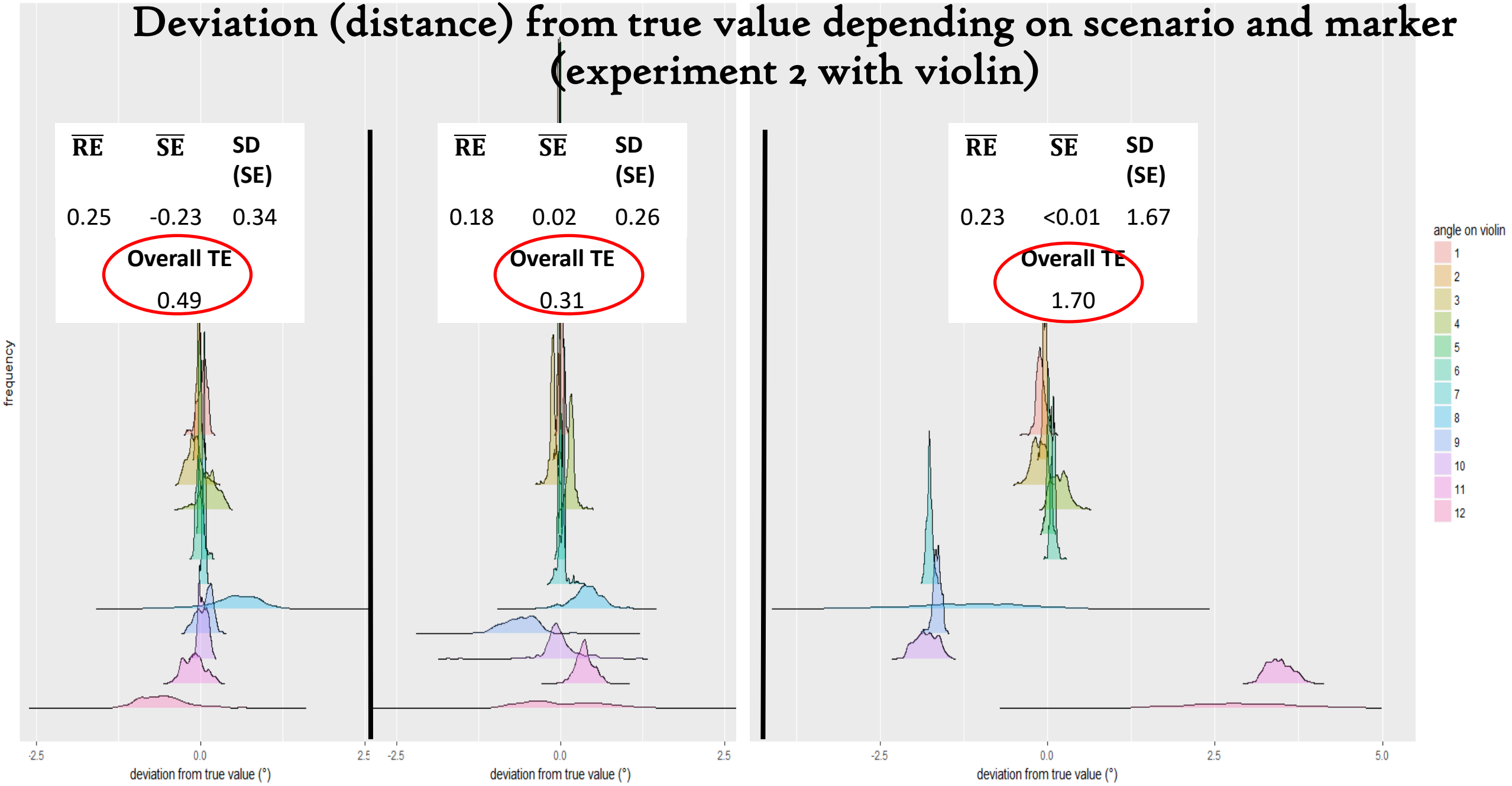
Out of lab with large volume Out of lab with small volume Lab

Deviation (distance) from true value depending on scenario and marker (experiment 2 with violin)



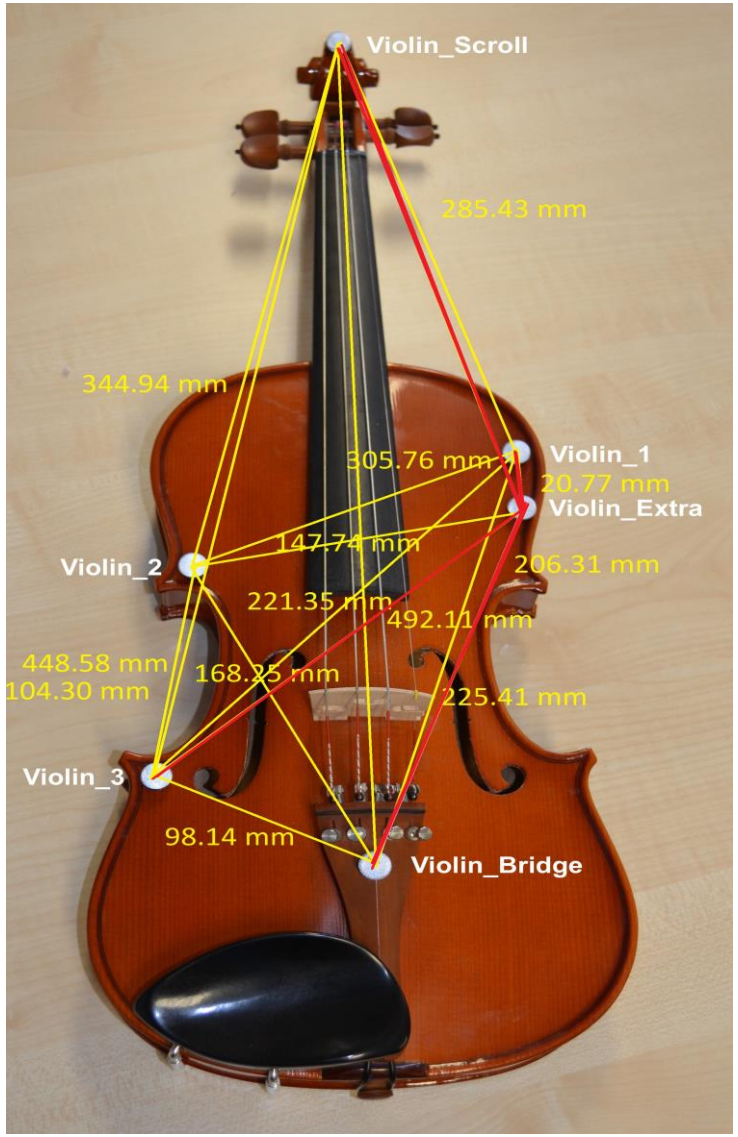
Out of lab with large volume Out of lab with small volume Lab

Deviation (distance) from true value depending on scenario and marker (experiment 2 with violin)

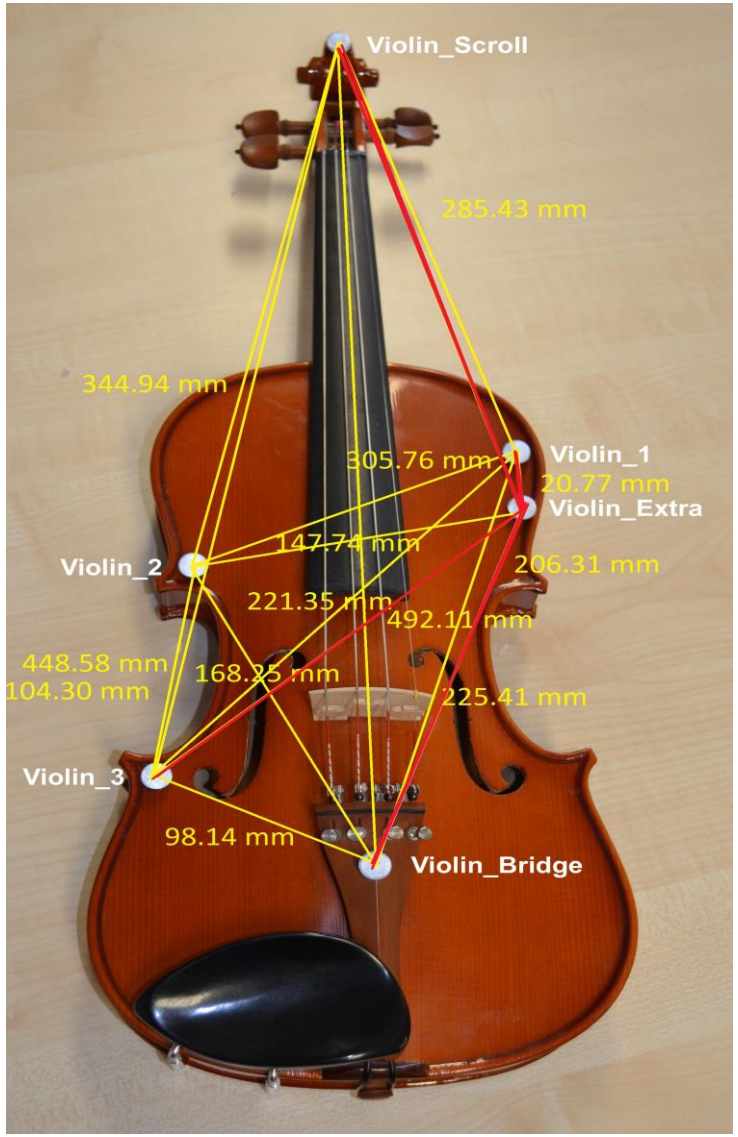


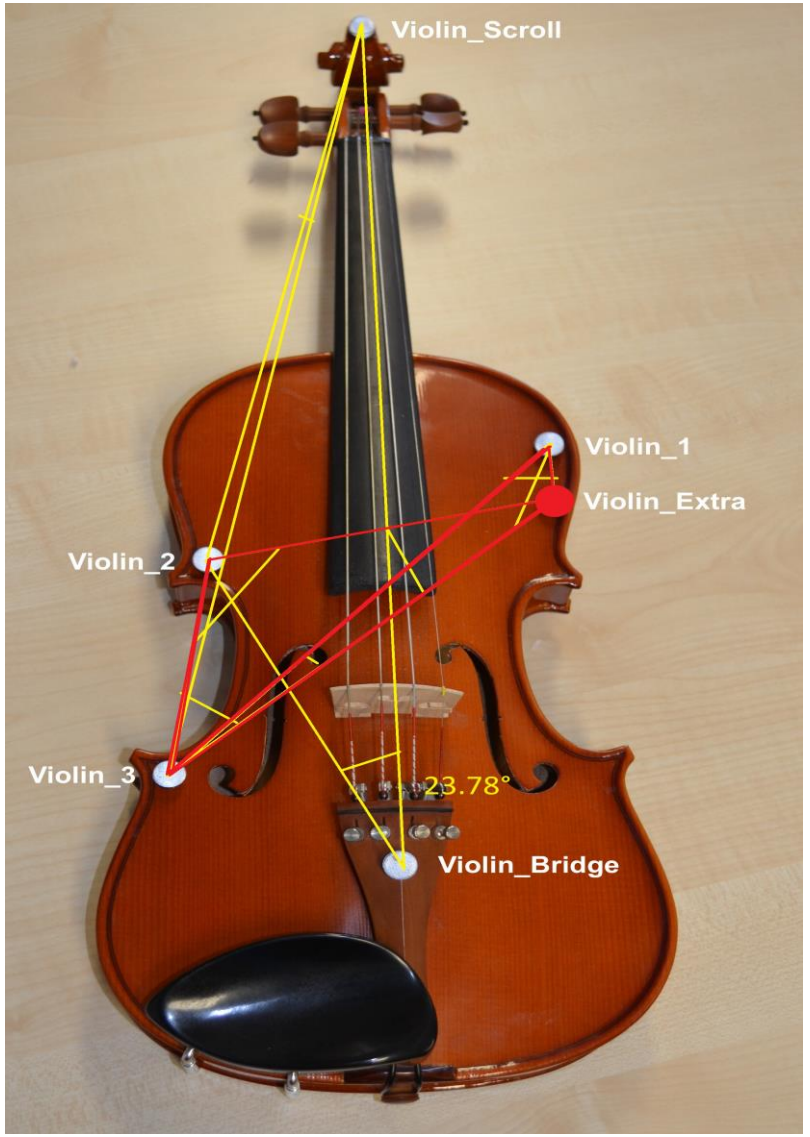
Out of lab with large volume Out of lab with small volume Lab

What is the problem?

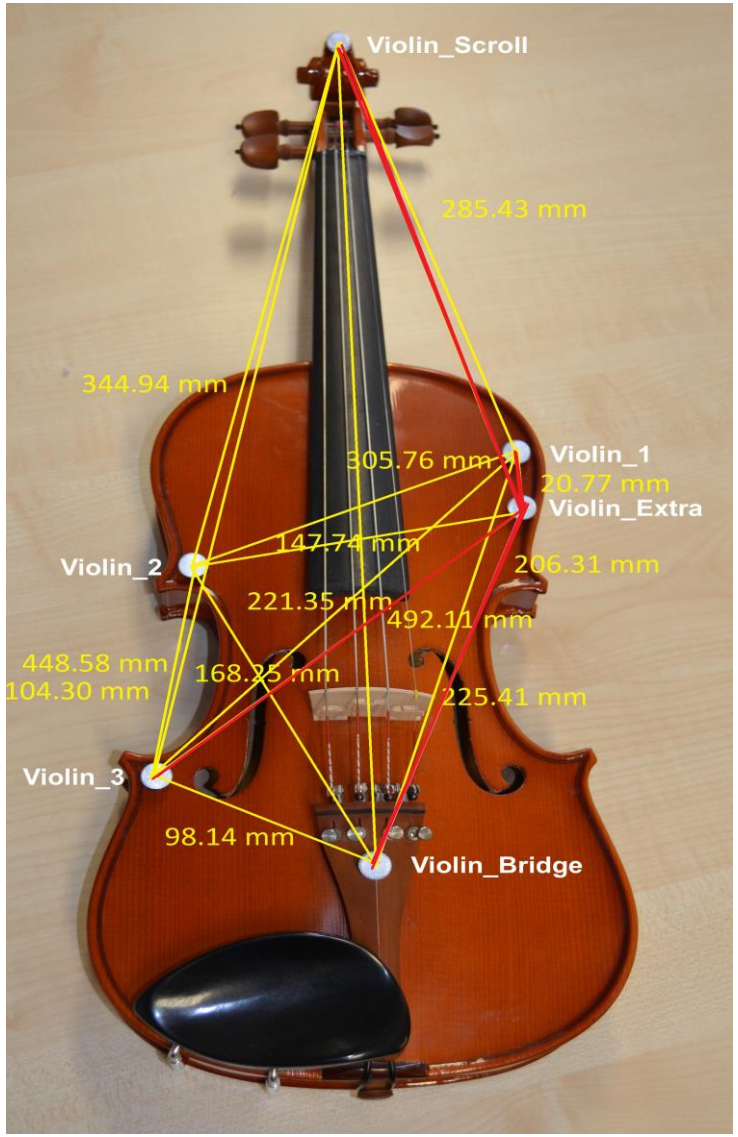


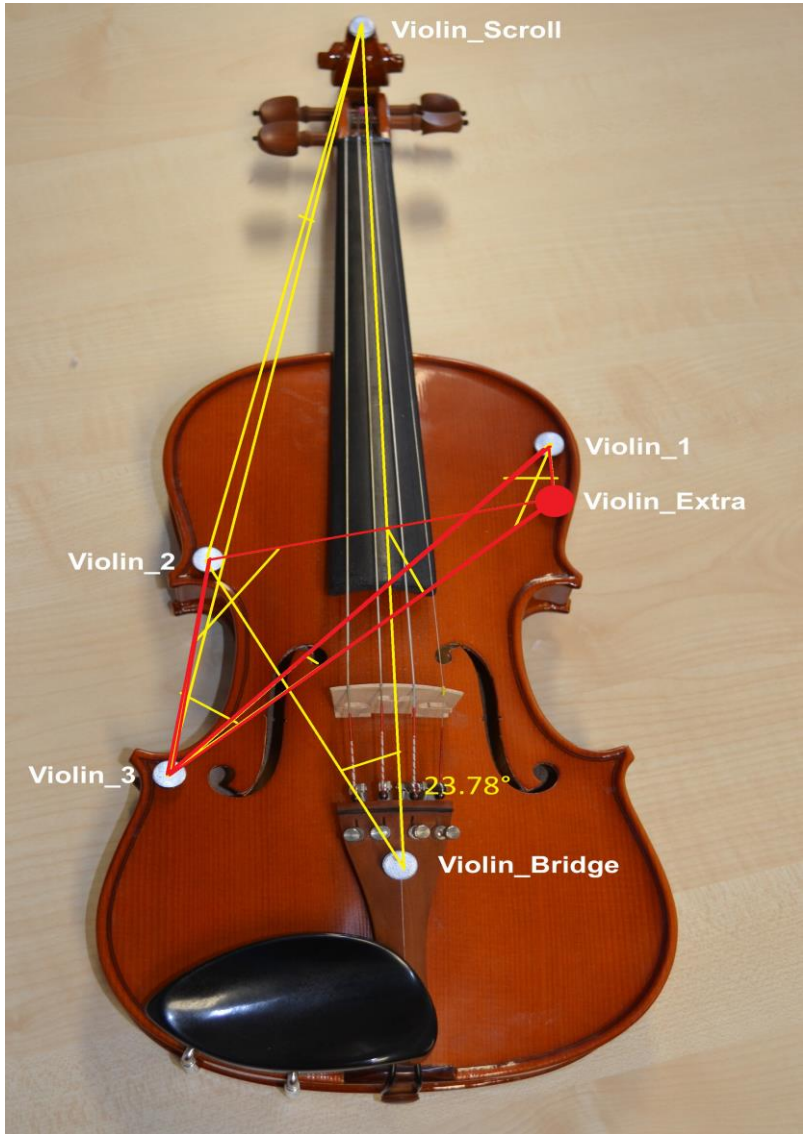
What is the problem?



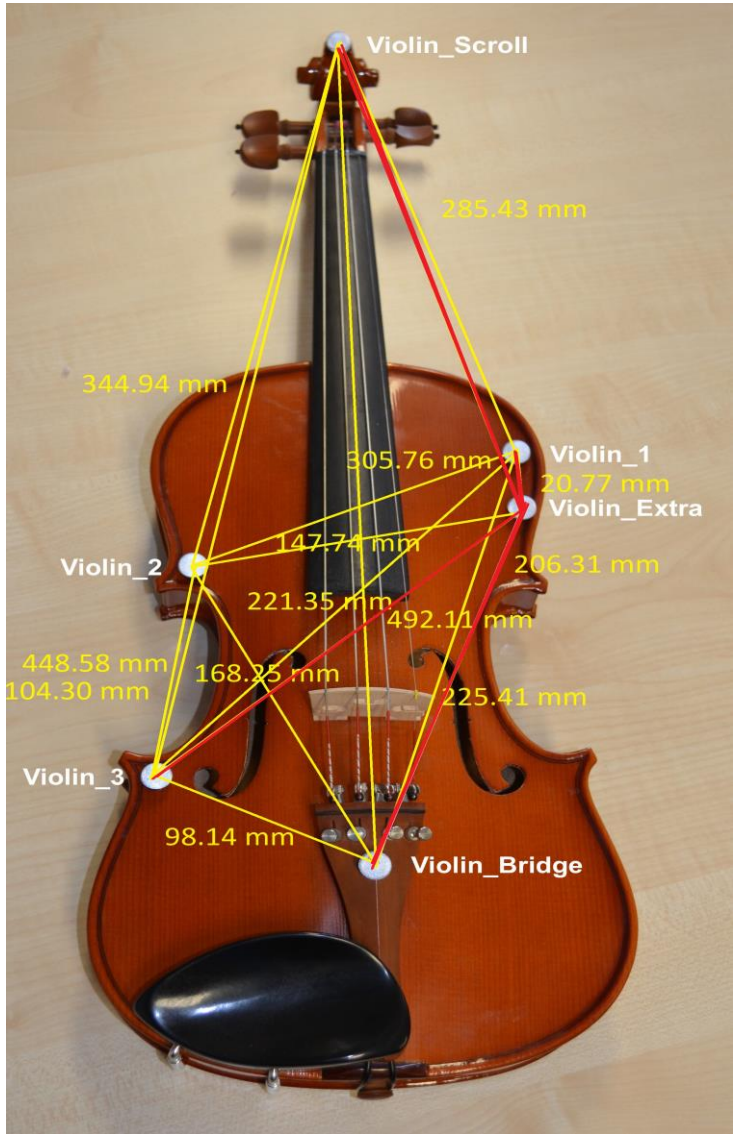


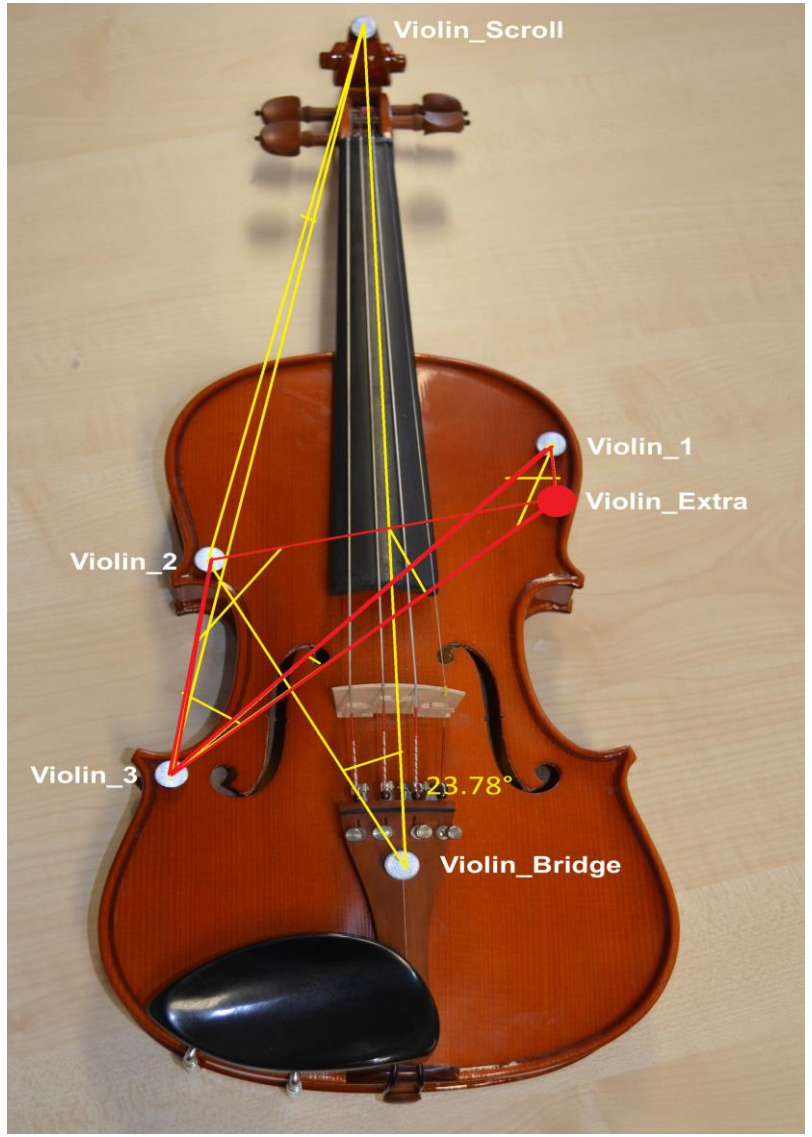
Merging of markers



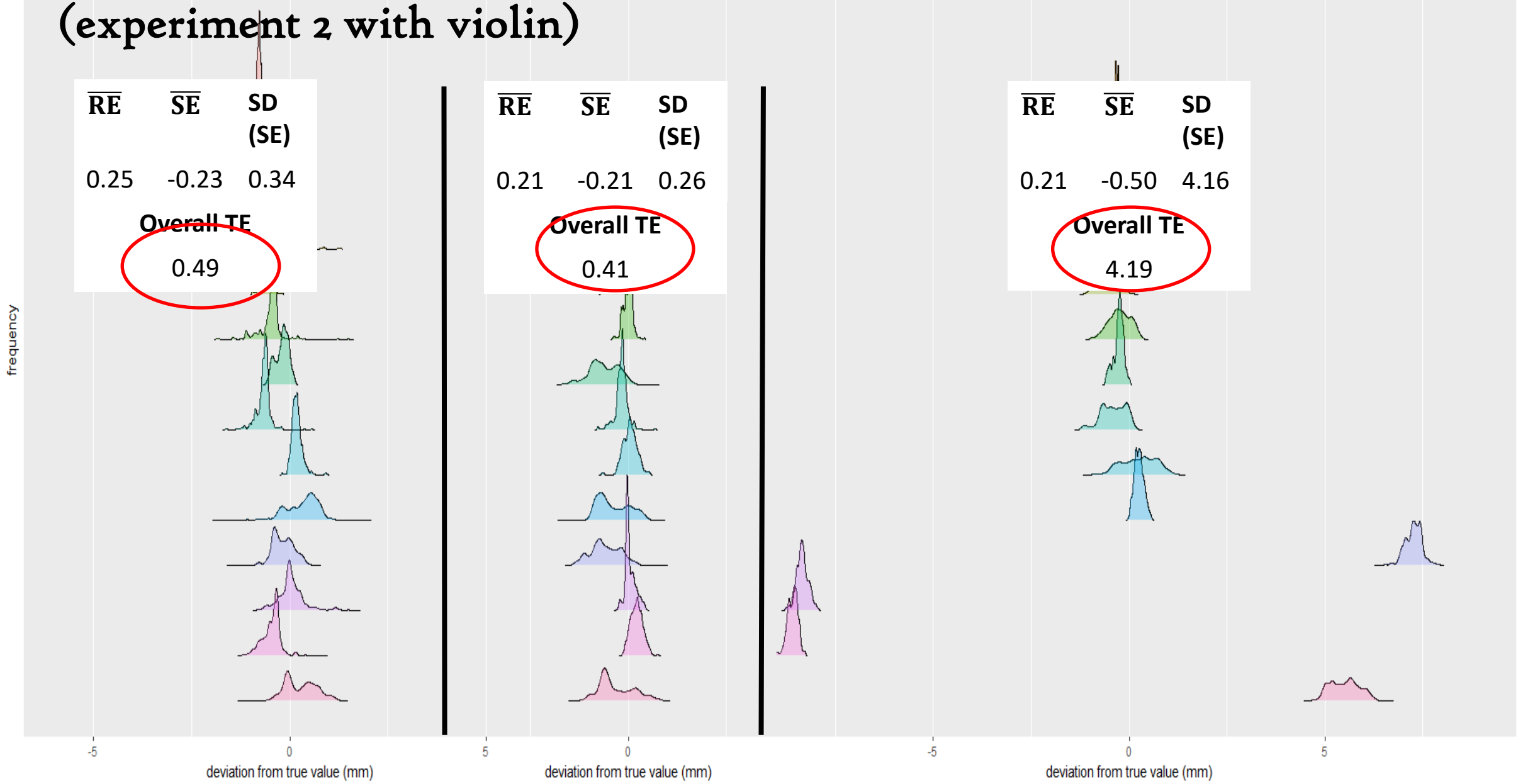


no reduction of accuracy under mobile conditions but due to measurement volume





Deviation (distance) from true value depending on scenario and marker (experiment 2 with violin)



Out of lab (8m x 4m x 2.5m)

Out of lab (5m x 3m x 2.5m

Lab (10m x 8m x 2.5m)

Discussion/Conclusion

- **no loss** of accuracy **out of lab**
- **Large** volume (long distance of cameras) leads to **merging** of close markers
- **No conclusion** about accuracy when markers are **changing positions**

→**however:** no assessment of accuracy possible due to **missing gold standard**

- **no guarantee** of accuracy with calibration by **wand**

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Discussion/Conclusion

Message :

- Measureing **out of lab** is without reducing **accuracy**
- **BUT**: be aware of **optimal volume** espacially with **close markers!**

References

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